PAPERS

Energetic saving in the School's Facilities in Sabadell (Spain)

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BACKGROUND

The city councilors for the Environment and Sustainability and the Region of the Town Hall of Sabadell have signed an agreement of collaboration with the *Universitat Politècnica de Catalunya* (UPC)'s Interdisciplinary Center for Sustainable Technology, Innovation and Education (CITIES) to develop an Energy Savings Plan for Municipal Facilities (PE3).

This improvement plan aims to improve energetic efficiency in the city's different sectors of activity, promoting the use of renewable energy and decreasing the environmental impact of energy consumption. This plan has been categorized into the specific areas of education, sensitization and energetic counseling, and was developed by the Energy Efficient Buildings group, the City Council of Environment and Sustainability and the Regional City Council of the Town Hall of Sabadell. It was developed in collaboration with the Interdisciplinary Center for Sustainable Technology, Innovation and Education *(CITIES)* of the *Universitat Politècnica de Catalunya (UPC).*

The Plan, initiated in April 2005, is made up of three phases:
• Phase 0: Initial diagnosis and definition of lines of action
• Phase 1: Development of specific studies (energy auditing in buildings by sectors)
• Phase 2: Execution of Plan and prioritization of action

The three Phases have been carried out and we believe that now is the time to spread the word about it and to begin evaluating the obtained results.

ENERGY SAVINGS PLAN FOR MUNICIPAL FACILITIES (PE3)

During the development of Phase 2, the following steps were taken:

1. The standardization of an *ad hoc* energy auditing protocol for the Sabadell Town Hall, based on the auditing methodology developed for UPC buildings [1], and the establishment of a methodology applicable to any short-term auditing of municipal offices or facilities.
2. A detailed study of preschool, daycare and primary education centers, allowing for the overall characterization of generalized energy savings measures.
3. The drafting of a Plan of Action for the development and evaluation of proposals for improvement.

4. And, the drafting of a General Plan of Action for all municipal facilities (educative, sport, cultural and administrative) starting from the pre-diagnosis of Phase 0, and taking into account the specific steps of Phase 1.

This paper briefly shows the results of the energy savings study in different PECs (Primary Education Centers) in Sabadell. School facilities are an appropriate place to start because a direct and permanent link with the education of tomorrow's citizens is fundamental for improving construction and environmental sensibility.

METHODOLOGY

The process of establishing energy savings criteria in buildings calls for measures and collaboration at different levels. The participation and involvement of all intervening agents in the process are therefore necessary from the start.

In accordance with the objectives defined in PE3 and after some experiments carried out in municipal buildings in Sabadell, we present here what could be considered a basic work scheme. It is organized into four main differentiated phases in addition to the previous Phase 0 of pre-diagnosis which defines the scenario for initiating work.

- Phase 0: Pre-diagnosis
- Phase 1: Data collection
- Phase 2: Assessment
- Phase 3: Diagnosis and lines of action
- Phase 4: Intervention proposals

Phase 0: Pre-diagnosis

This is the first phase of the entire process and is oriented to discovering energy dysfunctions in a building.

As mentioned, any initiative which aims to define improvement, savings or energy efficiency criteria needs to previously establish the starting scenario with which to evaluate the potential for improvement and the viability of objectives. If the goal, for example, is to reduce a building's consumption by 50%, we need to establish the reference parameters for this percentage: Annual consumption; Total resource consumption; Consumption of specific energetic uses; Consumption per sqm, etc.

These reference parameters require sufficient information in order to identify resource consumption trends, factors which may be conditioning these trends, and, depending on how detailed the available information is, the specific lines of action to be developed.

Since the purpose is to define the starting scenario from existing information, the pre-diagnosis is key as the final diagnosis will be based on the results obtained once the study is finished. It will be carried out with a much more detailed analysis at another level after collecting all of the specific information.

In the case of large-scale work, such as a group of municipal facilities [2], the pre-diagnosis must be carried out prior to the detailed study itself. This could result in the need to carry out a complete energy audit.

PAPERS

Phase 1: Data collection

This is the first part of the complete process, and the good results and reliability derived from the following work phases rely on this phase. Access to the different information sources must therefore be facilitated by the building's managers and users. With this idea in mind, we have established three types of access:

• **Basic level access BL (NB)**: for buildings with scarce information or data to be verified.

• **Mid level access ML (NM)**: for buildings with partial available data in need of improvement in quantity and quality.

• **Detailed level access DL (ND)**: for buildings with great available data of good quality which only needs verification.

Figure 1: PEC Espronceda, Sabadell

The types of collected data must be distinguished into "static data" and "dynamic data", according to the modifications registered over time. A building's architectonic characteristics, which in principle do not vary, are considered "static", while a building's intensity of use or conditions of comfort are considered "dynamic". We make this distinction because each of these data types requires work from different areas and must be reflected in specific document formats.

Phase 2: Assessment

Once the data collection process is finished, which is the longest and most demanding of precision in order to produce reliable documents, an assessment is made which will be used for the diagnosis of the building being studied.

The collected data is processed in order to assess the following:

• Resource consumption according to meter monitoring when possible.
• Resource consumption according to computerized meter readings and bill data.
• The characterization of energy consuming systems and devices which cover the demand for air conditioning, heating and lighting.
• And, when possible, operating conditions (occupation, maintenance and management, and comfort parameters).

PAPERS

With this data we can form what we call an index or significant values which allow us to characterize a building.

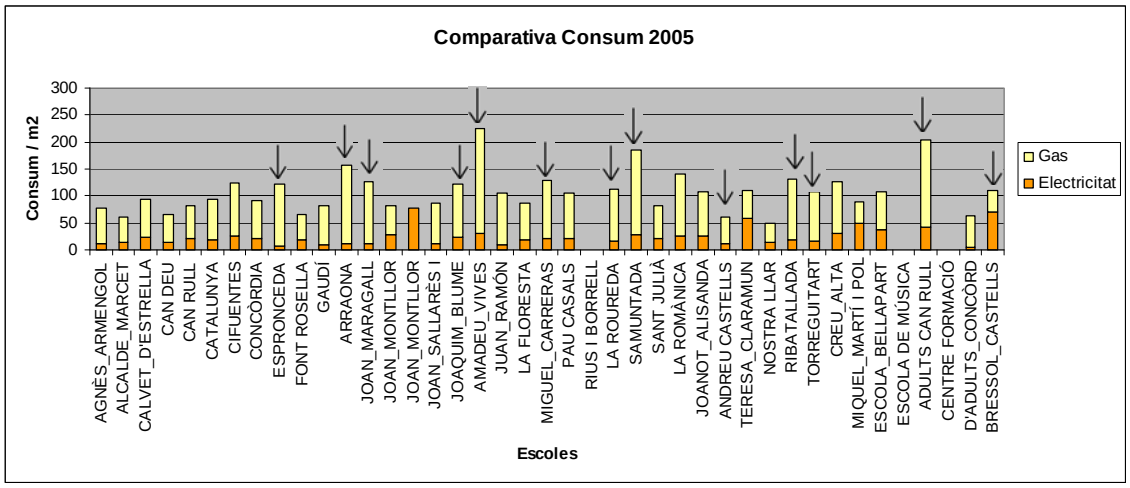

Figure 2: Comparative consumption data between the different PECs of Sabadell

Using the indexes or significant values we are able to transform the collected data from different units with diverse tools, into values which are unified and comparable (kWh/sqm, lux/space, etc.) to those of similar buildings. Given that there are many types of indexes that characterize buildings by energy use, the most appropriate one must be selected depending on the objective of the analysis. In our case, we have used the indexes in relation to other buildings with similar characteristics, for example to compare the resource consumption per sqm/person/year, etc.
At this point the data collection becomes significant, since the mechanical task of collection and registry is transformed into significant indexes that allow us to compare a building with the reference indexes or **reference parameters**. This allows us to define the starting scenario from which to identify a building's opportunities for improvement.

In this phase the diagnosis can be made, after assessing the data and comparing it with the reference values. From this point on, the lines of action and intervention can be defined.

Phase 3: Diagnosis

The recognition of a building's energy consumption and its possibilities for improvement is obtained through partial diagnoses in each of the areas analyzed: architectonic structure, energy systems, usage and management. This diagnosis can be a starting point for defining the lines of action to be taken for improving the building's energy efficiency and resource consumption, taking into account its technical, economic and logistic viability.

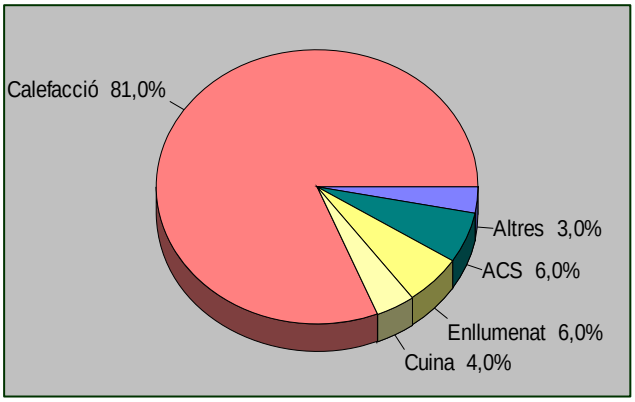

Figure 3: Graph of energy consumption distribution in the school sector

With this diagnosis we should be able to detect the different possibilities for improvement in each of the areas mentioned, as well as evaluate proposals depending on the difficulties involved in their execution. In the case of a building in which lines of improvement are identified in both the structure and in the functioning of air conditioning and heating, and supposing that both would provide similar energy savings, the necessary investment for each must be determined in terms of costs and logistics before deciding on an intervention proposal.

The adaptation and ascertainment of the diagnosis will therefore depend directly on the quality of the information gathered during the data collection phase, and on the rigor with which the evaluation of the results is carried out**.**

Phase 4: Lines of action

And finally, from the diagnosis we can identify the shortages in a building and consider specific solutions to remedy them. The different proposals are grouped into what we call lines of action, which are determined by the methodology used during the data collection and assessment phases. They are defined as such:

• Lines of action related to the structure: those which have to do with the building's architectonic characteristics and construction and specifically with its physical envelope (roofing, vertical exterior coverings, grounds, etc.). This type of action has the objective of reducing energetic demand.

ZONA CLIMÁTICA C2

Transmitancia límite de muros de fachada y cerramientos en contacto con el terreno	U_{Mlim}: 0,73 W/m^{2}K
Transmitancia límite de suelos	U_{Slim}: 0,50 W/m^{2}K
Transmitancia límite de cubiertas	U_{Clim}: 0,41 W/m^{2}K
Factor solar modificado límite de lucernarios	F_{Llim}: 0,32

	Transmitancia límite de huecos[1] U_{Hlim} W/m^{2}K				Factor solar modificado límite de huecos F_{Hlim}					
					Baja carga interna			Alta carga interna		
% de huecos	N	E/O	S	SE/SO	E/O	S	SE/SO	E/O	S	SE/SO
de 0 a 10	4,4	4,4	4,4	4,4	-	-	-	-	-	-
de 11 a 20	3,4 (4,2)	3,9 (4,4)	4,4	4,4	-	-	-	-	-	-
de 21 a 30	2,9 (3,3)	3,3 (3,8)	4,3 (4,4)	4,3 (4,4)	-	-	-	0,60	-	-
de 31 a 40	2,6 (2,9)	3,0 (3,3)	3,9 (4,1)	3,9 (4,1)	-	-	-	0,47	-	0,51
de 41 a 50	2,4 (2,6)	2,8 (3,0)	3,6 (3,8)	3,6 (3,8)	0,59	-	-	0,40	0,58	0,43
de 51 a 60	2,2 (2,4)	2,7 (2,8)	3,5 (3,6)	3,5 (3,6)	0,51	-	0,55	0,35	0,52	0,38

[1] En los casos en que la transmitancia media de los muros de fachada U_{Mm}, definida en el apartado 3.2.2.1, sea inferior a 0,52 se podrá tomar el valor de U_{Hlim} indicado entre paréntesis para las zonas climáticas C1, C2, C3 y C4.

Figure 4: Table of limit transmittance per climactic zone C2, according to the CTE. [3]

Figure 5: Facade protected with vegetation and unprotected envelope.

• Lines of action related to systems and facilities: covering all interventions which may improve the functioning of equipment and systems that deal with the energetic demand of a building (lighting, air conditioning and heating equipment, flux regulators, etc.).

Figure 6: Conduction with excessive runoff piping on the outside of the building.
Figure 7: Installation of solar plates for sanitary hot water.

• Lines of action related to energy resource management: including those identified with a building's occupation characteristics, uses and functions (schedules, periods, etc.).

NOM DEL CEIP					
Qüestionari avaluació del confort en l'ús	☺	·	☹	?	**comentaris**
La climatització a l'espai de treball					
Existeix termòstat en l'espai de treball					
La temperatura a l'estiu està a 25ºC (o més o menys)					
La temperatura al hivern està a 20ºC (o més o menys)					
Al hivern cal obrir finestres per excés de calor					
L'espai s'escalfa amb radiació solar					
L'espai s'escalfa amb combustible gas					
L'espai s'escalfa amb energia elèctrica					
Les finestres són estanques					
La finestra està encarada a sud					
La finestra està encarada a nord					
La finestra està encarada a est					
La finestra està encarada a oest					
Les finestres disposen de persianes					
La caixa de persiana està aïllada i és estanca					
Les persianes es poden pujar/baixar per l'usuari					
Les finestres disposen de cortines					
A l'estiu cal portar jaqueta					

Figure 8: Model of data collection file related to area use.

Each of the identified lines of action must be evaluated in three aspects: the effect on a building's energy demand, overall consumption and the percentage of potential savings and technical and economic viability.

Proposal of action

With all of the difficulty involved in defining overall lines of action for all of the educational facilities in the town of Sabadell, and after having carried out the consumption assessment and detailed studies of some PECs with excessive consumption, we believe that certain patterns can be established from which the Energy Savings Plan for Municipal Facilities (PE3 and PE4) can be designed.

In drafting these general lines of action, some specific proposals have been included which were extracted from various energy audits carried out in Phase 2 of the Plan: PEC “Miquel Carreras”; the sports facility “Municipal Sports Pavilion Esportiu Can Balsach”; the cultural facility “Vapor Badia Library”; and the administrative facility of the “Can Marcet” building.

We need to make it very clear that an advance toward more efficient and responsible energy consumption does not necessarily mean reducing the parameters of comfort within the buildings. What’s more, it specifically means an improvement in environmental quality through a reduction of greenhouse gas emissions, and, in the end, an economic savings from a reduction in consumption. Savings opportunities and a possible reduction in consumption must therefore be discovered for each building.

We’ve established a Decalogue of possible savings opportunities that we’ve detected during the drafting of the different work phases of PE3. Granted not all of them will be applicable in all of the buildings, and for each facility a detailed study must be carried out so as to establish what the different lines of action mean in terms of energy savings.

1. Citizen commitment
2. Control of expenses and energetic building management
3. Summer is summer and winter is winter
4. The skin of the building
5. Defining a plan for reform in existing buildings
6. System performance
7. Solar ordinance and other renewable energies
8. Reactive energy
9. Light savings
10. Light maintenance

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[2] Rodríguez, Inmaculada; Bosch, Montse, “Involvement of Final Architecture Diploma Projects in the Analysis of the UPC Buildings Energy Performance as a way of Teaching Practical Sustainability”. *Journal of cleaner production,* 14 (9-11): 958-962. ISSN: 0959-6526 (2006).

[3] Real Decreto 314/2006, 17th March, approval/sanction of the “Código Técnico de la Edificación”. Ministerio de la Vivienda, Spain.